PB-239 577

ELBOW LAKE, ST. LOUIS COUNTY, MINNESOTA

Pacific Northwest Environmental
Research Laboratory

Prepared for:

National Environmental Research Center
Minnesota National Guard
Minnesota Pollution Control Agency

December 1974

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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

ELBOW LAKE

ST. LOUIS COUNTY

MINNESOTA

EPA REGION V

WORKING PAPER No. 97

WITH THE COOPERATION OF THE

MINNESOTA POLLUTION CONTROL AGENCY

AND THE

MINNESOTA NATIONAL GUARD

DECEMBER, 1974

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

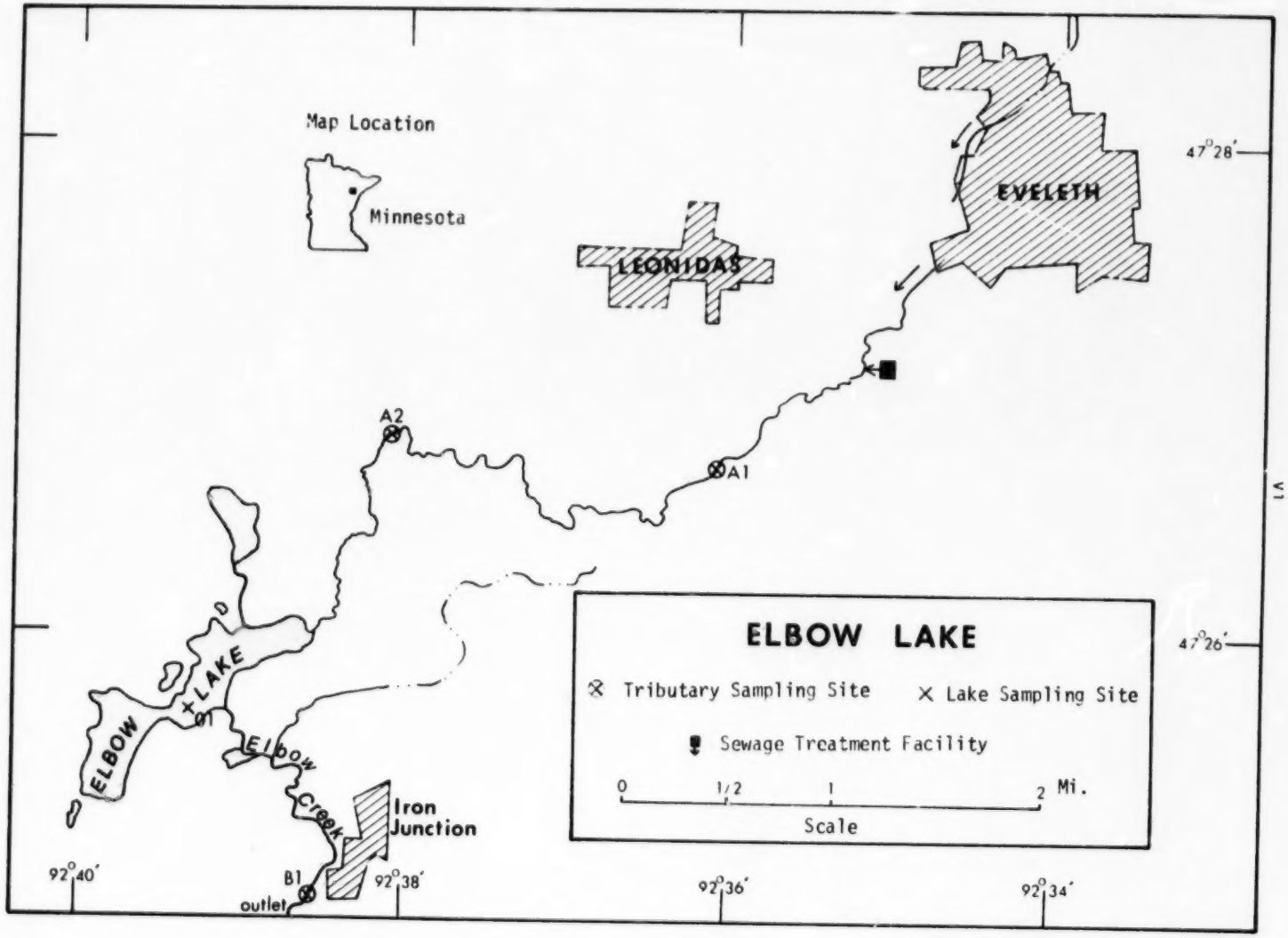
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


Map Location
Minnesota
LEONIDAS
EVELETH
47°28'
47°26'
A2
A1
ELBOW LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0
1/2
1
2 Mi.
Scale
ELBOW LAKE
Elbow Creek
Iron Junction
B1
outlet
92°40'
92°38'
92°36'
92°34'

ELBOW LAKE

STORET NO. 2725

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Elbow Lake is eutrophic. Of the 60 Minnesota lakes sampled in the fall when essentially all were well-mixed, only three had more mean total phosphorus, only two had more mean dissolved phosphorus, and only two had more mean inorganic nitrogen. Of the 80 Minnesota lakes sampled, 18 had less mean chlorophyll a, and 17 had greater Secchi disc transparency.

Survey limnologists noted an intensive bloom of algae matting the lake surface during the September sampling.

B. Rate-Limiting Nutrient:

The algal assay results show that Elbow Lake was nitrogen limited at the time the assay sample was collected. The lake data indicate nitrogen limitation at the other sampling times as well (N/P ratios were less than 2/1).

C. Nutrient Controllability:

1. Point sources--During the sampling year, Elbow Lake received a total phosphorus load at a rate in excess of that proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 12). Of this load, it is estimated that the City of Eveleth contributed over 98%.

It is calculated that complete removal of phosphorus from the Eveleth effluent would reduce the phosphorus load to 1.2 lbs P/acre/yr or 0.14 $g/m^2/yr$ which is less than an oligotrophic rate. If this degree of reduction can be achieved, the trophic condition of Elbow Lake should be significantly improved.

2. Non-point sources--Non-point sources are estimated to have contributed less than 2% of the total phosphorus load reaching Elbow Lake during the sampling year.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 171 acres.
2. Mean depth: 10.3 feet.
3. Maximum depth: 20 feet.
4. Volume: 1,761 acre/feet.
5. Mean hydraulic retention time: 296 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Unnamed Creek (A-1)	4.6 mi^2	2.2 cfs
Minor tributaries & immediate drainage -	1.4 mi^2	0.8 cfs
Totals	6.0 mi^2	3.0 cfs

2. Outlet -

Elbow Creek	6.3 mi^2**	3.0 cfs

C. Precipitation***:

1. Year of sampling: 28.0 inches.
2. Mean annual: 26.9 inches.

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† DNR survey map (1968); mean depth by random dot method.
* Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods".

III. LAKE WATER QUALITY SUMMARY

Elbow Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one station on the lake and from a number of depths (see map, page vi). During each visit, a single depth-integrated (near bottom to surface) sample was collected for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was collected for algal assays. Also each time, a depth-integrated sample was collected for chlorophyll a analysis. The maximum depth sampled was 9 feet.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the lake was essentially well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

		FALL VALUES (10/19/72)		
Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	3.8	4.4	4.4	5.1
Dissolved oxygen (mg/l)	7.3	7.3	7.3	7.4
Conductivity (μmhos)	300	300	300	300
pH (units)	7.5	7.5	7.5	7.5
Alkalinity (mg/l)	87	87	87	88
Total P (mg/l)	1.320	1.347	1.340	1.380
Dissolved P (mg/l)	1.260	1.267	1.260	1.280
NO_2 + NO_3 (mg/l)	0.280	0.303	0.310	0.320
Ammonia (mg/l)	1.740	1.753	1.750	1.770
		ALL VALUES		
Secchi disc (inches)	57	75	72	96

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/08/72	1. Anabaena	3,960
	2. Schroederia	470
	3. Chroococcus	54
	4. Mallomonas	54
	5. Flagellates	36
	Other genera	-
	Total	4,574
09/09/72	1. Anabaena	1,733
	2. Dinobryon	30
	3. Melosira	15
	4. Navicula	8
	5. Epithemia	8
	Other genera	45
	Total	1,839
10/19/72	1. Flagellates	1,601
	2. Fragilaria	565
	3. Anabaena	527
	4. Melosira	490
	5. Aphanothece	264
	Other genera	1,186
	Total	4,633

2. Chlorophyll *a* -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
07/08/72	01	22.4
09/09/72	01	3.6
10/19/72	01	2.9

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	1.100	1.490	47.6
0.005 P	1.105	1.490	40.6
0.010 P	1.110	1.490	41.1
0.020 P	1.120	1.490	45.2
0.050 P	1.150	1.490	54.5
0.050 P + 10.0 N	1.150	11.490	286.4
10.0 N	1.100	11.490	269.5

2. Discussion -

The control yield of the assay alga, *Selenastrum capricornutum*, indicates that the potential primary productivity of Elbow Lake was very high at the time the sample was collected. The lack of significant increases in yields with increased levels of ortho-P and the great increase in yield over the control with the addition of only nitrogen shows that the lake was strongly nitrogen limited.

The field data also indicate that the lake was nitrogen limited. Nitrogen to phosphorus ratios were less than 7 to 1 during the three samplings.

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of May and August when two samples were collected. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

The phosphorus load estimated for the City of Eveleth was slightly higher than the phosphorus load calculated at station A-1. Therefore, the background nutrient loads for station A-1 were estimated by using the means of the nutrient loads, in lbs/mi^2/year, at station B-1 of nearby Mashkenode Lake and multiplying the means by the station A-1 area in mi^2. The nutrient loads for the outlet were calculated using mean annual concentrations and mean annual flows at station B-1.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient loads, in lbs/mi^2/year, at station B-1 of Mashkenode Lake and multiplying the means by the ZZ area in mi^2.

Nutrient loads from the City of Eveleth were estimated at 2.5 lbs P and 7.5 lbs N/capita/year.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Eveleth	4,721	act. sludge	0.472**	Unnamed Creek to Elbow Lake

2. Known industrial - None

* Anonymous, 1974.
** Estimated at 100 gal/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek (A-1)	140	1.2
b. Minor tributaries & immediate drainage (non-point load) -	40	0.3
c. Known municipal STP's -		
Eveleth	11,800	98.3
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	30	0.2
Total	12,010	100.0

2. Outputs -

Lake outlet - Elbow Creek 4,030

3. Net annual P accumulation - 7,980 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek (A-1)	5,770	12.9
b. Minor tributaries & immediate drainage (non-point load) -	1,760	3.9
c. Known municipal STP's -		
Eveleth	35,410	79.4
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	1,650	3.8
Total	44,590	100.0

2. Outputs -

Lake outlet - Elbow Creek 13,880

3. Net annual N accumulation - 30,710 pounds

* See Working Paper No. 1.

D. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	70.2	46.7	278.3	194.4
grams/m^2/yr	7.87	5.23	31.2	21.8

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Elbow Lake:

"Dangerous" (eutrophic rate)	0.40
"Permissible" (oligotrophic rate)	0.20

V. LITERATURE REVIEWED

Anonymous, 1974. Wastewater disposal facilities inventory. MPCA, Minneapolis.

Schilling, Joel, 1974. Personal communication (lake map). MPCA, Minneapolis.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. A. Hydrol.

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2725 ELROY LAKE

TOTAL DRAINAGE AREA OF LAKE 6.30

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2725A1	4.55	0.11	0.11	0.34	11.00	5.39	3.03	2.23	0.62	0.86	1.30	0.80	0.22	2.18
2725R1	4.10	0.15	0.15	0.66	15.30	7.58	4.17	3.14	0.91	1.20	1.90	1.19	0.30	3.05
2725Z7	1.75	0.34	0.12	0.16	3.94	2.06	1.18	0.87	0.24	0.36	0.52	0.30	0.08	0.81

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 6.30
SUM OF SUB-DRAINAGE AREAS = 6.30

TOTAL FLOW IN = 35.98
TOTAL FLOW OUT = 36.65

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2725A1	10	72	0.81	15	0.80				
	11	72	0.40	12	0.51				
	12	72	0.14						
	1	73	0.09	9	0.10				
	2	73	0.11						
	3	73	1.15	9	0.20				
	4	73	2.42	18	2.20				
	5	73	4.19	2	2.70	19	2.00		
	6	73	2.15	7	1.20				
	7	73	0.98						
	8	73	1.19	14	2.40	25	0.94		
	9	73	0.51	23	0.30				
2725R1	10	72	1.19	15	1.20				
	11	72	0.60	12	0.80				
	12	72	0.20						
	1	73	0.13	9	0.10				
	2	73	0.15						
	3	73	1.41	9	0.30				
	4	73	3.37	18	3.00				
	5	73	5.76	2	3.80	19	2.80		
	6	73	2.94	7	1.70				
	7	73	1.34						
	8	73	1.74	14	1.06	25	1.40		
	9	73	0.71	23	0.50				
2725Z7	10	72	0.32	15	0.30				
	11	72	0.15	12	0.21				
	12	72	0.05						
	1	73	0.03	9	0.03				
	2	73	0.03						
	3	73	0.34	9	0.10				
	4	73	0.87	18	0.80				
	5	73	1.57	2	1.06	19	0.80		
	6	73	0.84	7	0.50				
	7	73	0.38						
	8	73	0.46	19	1.00	25	0.40		
	9	73	0.21	23	0.13				

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 72/12/10

272501
47 29 40.0 092 37 18.0
ELROY LAKE
27 MINNESOTA

11EPALES 2111202
3 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CONDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/04	14 00	0000	20.5	11.8	57	266	9.40	97	0.050	0.070	0.900	0.720
72/09/09	14 00	0000			72	272	8.35	96	0.110	0.370	1.440	1.270
	14 00	0004	16.5	7.7		274	8.95	95	0.120	0.350	1.420	1.290
	14 00	0008	14.2	5.1		278	8.90	96	0.100	0.280	1.400	1.260
72/10/19	14 00	0000			96	300	7.50	87	0.280	1.770	1.320	1.260
	14 00	0004	9.8	7.4		300	7.50	87	0.310	1.740	1.340	1.280
	14 00	0008	9.1	7.3		309	7.50	88	0.320	1.750	1.380	1.260

9/

DATE FROM TO	TIME OF DAY	DEPTH FEET	00217 CHLOROPHYL A UG/L
72/07/04	14 00	0000	22.43
72/09/09	14 00	0000	3.03
72/10/19	14 00	0000	2.21

J VALUE KNOWN TO BE [illegible]

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/30

2725A1 L52725A1
47 27 00.0 092 34 00.0
UNNAMED TRIB FROM ELEVETH AREA
27057 7.5 EVELETH
T/FLHOW LAKE
CO HWY 317 XING HELO EVELETH STP
11EPALFS 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/11/12	11 20		0.630	12.000	6.400	2.600	3.850
73/04/18	19 00		0.430	5.150	3.000	0.630	0.990
73/05/02	19 30		0.460		3.400	0.610	0.970
73/05/19	12 55		0.550	6.400	4.200	1.000	1.480
73/06/07	14 10		0.150		9.400	3.600	
73/08/19	14 15		0.100	3.200	0.040	1.700	1.880
73/08/25	17 45		0.030	12.000	10.950	2.900	3.670
73/09/23	11 15		0.195	11.500	9.700	3.000	3.400

STREET RETRIEVAL DATE 74/12/13

272542 LS272542
+47 27 00.0 092 35 00.0
UNNAMED TRIB FROM EVELETH AREA
27 7.5 EVELETH
I/ELMOW LAKE
CO HWY 19 XING N OF IRON JUNCTION
11PALES 2111204
4 6000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] DISSOLVED N-TOTAL MG/L	[illegible] TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	17 00		2.400	1.400	0.310	1.300	1.375
72/11/12	10 50		1.350	3.600	0.470	1.245	1.370
73/04/14	14 35		3.300	2.900	0.430	0.560	0.670
73/05/02	14 40		3.400		0.920	0.550	0.660
73/05/13	11 25		3.710	0.700	0.040	0.540	0.680
73/05/27	14 30		2.500		0.280	1.700	
73/08/13	15 00		7.400		1.200	1.550	1.600
73/08/29	17 30		4.500	2.600	1.150	1.500	2.100
73/09/24	11 35		1.100	3.400	0.355	0.043	1.900

STORET RETRIEVAL DATE 74/10/10

272581 LS272581
47 25 00.0 092 36 30.0
ELBOW CREEK
27 7.5 EVELETH
O/ELBOW LAKE
CO HWY 452 XING SW OF IRON JUNCTION
FEMALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO3&NO2-N TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	17 10		0.740	1.525	0.420	0.165	0.230
72/11/12	11 10		0.820	1.900	0.640	0.200	0.260
73/04/1-	14 45		0.250	2.600	0.100	0.270	0.450
73/05/02	13 15		0.220		0.023	0.240	0.450
73/05/19	13 10		0.210	0.365	0.117	0.410	0.450
73/06/07	14 25		0.220		0.420	0.940	0.900
73/07/19	14 08		0.870	0.560	0.046	0.910	0.930
73/08/25	17 35		0.315	0.900	0.240	0.870	0.900
73/09/24	11 25		0.650	4.100	0.560	0.147	0.415